Understanding the relationships between water quality, recreational fishing practices, and human health in Phoenix, AZ

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INTRODUCTION

Recreational fishing is a common hobby within the U.S., as approximately 33 million fishing licenses are issued each year and it is more popular than bowling, or playing basketball, soccer, or softball. While some individuals only fish for recreational purposes, there are still many that eat the fish that they catch, with even some populations whose main source of fish come from recreational fisheries (American Sportfishing Association, 2013). However, recreational fisheries are poorly regulated for fish consumption, as they are considered surface waters by federal and state governments. Therefore, anglers who regularly eat fish from recreational fisheries may be facing chronic disease causing pollutants that come from nonpoint sources.

Currently, the U.S. Environmental Protection Agency (EPA) sets guidelines for surface water quality standards for mainly aquatic life and swimming exposure, which state governments can choose or not choose to follow. These guidelines are set mainly for acute toxicity to chemicals and biological agents such as nutrient loads, which affect aquatic life, and bacteria, which affects swimmers. States are required to follow some sort of guidelines for recreational water protection even if they are not from the EPA, making the laws vary depending on the state (EPA 2012). All Arizona surface water quality is regulated by the Arizona Department of Environmental Quality (AZDEQ). They measure and regulate waters for acute toxicity issues and bacteria. However urban lakes in Phoenix are mainly controlled by the Arizona Game and Fish Department and the City of Phoenix Parks and Recreation Department. Generally, AZ Game and Fish stock the lakes with inspected fish, provide fish advisory and swimming information, and regulate licenses and fish withdrawals. The City of Phoenix maintains the park areas surrounding the lakes. Therefore, numerous governing entities for urban fisheries exist.

As mentioned earlier, because urban waters are only regulated for acute toxicity in fish consumption, chronic toxicity is largely unknown and unregulated. This study aims to bridge this gap by providing the evidence for greater chronic toxicity research and urban fishery water quality standards. It was hypothesized that many anglers were regularly eating fish from Phoenix urban fishing waters which contained potentially chronic disease causing contaminants. The study found that a majority percentage of recreational anglers surveyed eat fish from 6 contaminated urban fisheries in Phoenix, AZ, many living in low-income and minority neighborhoods. Pollutants were found through water sample analyses from each location, mostly originating from nonpoint sources. It was recommended that the various governing bodies of urban fisheries collaborate to generate unique solutions to water quality issues through an ecosystem approach, such as better fish advisories, more research, greater nonpoint source pollution controls, and community engagement. The findings and recommendations of this report will be published and given to the AZ Game and Fish Department in order to spur sustainable changes toward better urban fishery management.
METHODS

First, a literature review was conducted to find if the same study had been completed at Phoenix-metro fishing ponds. After it had been established that the same study had not been done, another literature review of similar studies in other areas was completed to understand the best way to frame the survey. Next, it was important to learn from online survey information and books about the most objective way to write the survey questions for optimal results. The survey was designed with 10 main questions with short sub-question, leading to about a 10-15 minute survey time. The questions aimed to capture how far anglers lived from the lakes, how many fish they caught and ate, how they prepared the fish for eating, who they shared their fish with, and their perceptions of environmental quality. An observation quality sheet was also created to capture the surveyor’s observation of the area and perception of environmental quality. After a few edits and trials, the survey and observation sheet were sent in and approved by an institutional review board.

The survey was then implemented at the 6 Phoenix fishing locations: Alvord Lake, Cortez Lake, Desert West Lake, Encanto Lake, Steele Indian School Lake, and Papago Ponds, in that order. Each location was surveyed on a Wednesday and a Saturday, twice in about a 4 month period, from September through December 2015. For example, Alvord Lake was the first location to be surveyed twice in one week, and then would be surveyed again after the 5 other locations were surveyed in their specific order. The same schedule was repeated for the remaining locations. Only individuals that were 18 years or older could participate in the survey. It was implemented by walking to each individual that was fishing, asking if they wanted to be surveyed, and recording the answers to the questions. Information about the background and purpose of the survey was given to each individual and their responses remained anonymous. The observation sheet, which recorded environmental quality information, bird species, and demographic data was also completed at each visit. Along with surveying, water quality samples were taken on the same days as the surveys for each location. Obtaining fish samples was unsuccessful and therefore only water sample data was used.

After obtaining survey and water sample data, the results were analyzed. The written survey and observation data were entered into an excel sheet, coded, counted, and made into charts and graphs of the information, in order to understand trends and relationships. At the Polidoro SWAT lab, located at ASU-West campus, water samples were extracted and analyzed by Gas Chromatography/Mass Spectroscopy to detect and quantify organic pollutants. Both types of results, along with Phoenix demographic information, were interpreted to demonstrate the relationships between recreational fishing practices, water pollutants, and human health.
RESULTS

Water Quality Sample Results

The combined results from the water samples from all locations included a list of various chemicals, which mostly included polychlorinated biphenyls (PCBs), pesticides, phthalates (plastics), and several unknown chemicals. Alvord Lake contained 15 different pollutants. Cortez Lake contained 10 different pollutants. Desert West Lake contained 9 different pollutants. Encanto had 10 different pollutants. Steele Indian School Lake had 12 different pollutants. Papago Ponds had 11 different pollutants. The most common pollutants that were present in every lake included: 2,6-Di-tert-butyl-4-methyl (BHT), Diethyl phthalate, Dibutyl phthalate, Bentiocarb, Malathion, and Di(2-ethylhexyl) phthalate. The levels detected in surface water need to be extrapolated to fish consumption levels by the Polidoro lab in order to best understand potential for chronic toxicity. Appendix A has the full list of pollutants by location.

Survey Results

While there was a total of 10 questions with sub questions, some information from the study results was omitted in order to highlight the most significant aspects. All survey questions can be found in Appendix B. Question 1 asked how far anglers lived from the fishing location to capture possible socioeconomic environmental justice issues, which is explained in the discussion section. Question 1 found that the time traveled to the pond/lake, primarily by car, was mostly from 0-20 minutes, with the majority of all respondents 0-10 minutes away (52% of all responses), as shown in Figure 1. These results demonstrate that most people lived relatively close to the parks that they fished at.

Question 3 asked what times of the year individuals fished and 44% of all anglers responded during “Stocking Season,” 40% responded “All Year,” 13% responded with during “Off Season” and 3% responded “Inconsistent.” The stocking season is in the fall through spring months. Off season time includes only the summer months, while inconsistent timing is on and off throughout the year. These results demonstrate that fishing is going on during the majority
months out of the year rather than in the off season which include less months than the stocking season.

Question 5 captured how many individuals are eating fish from the recreational fishing waters in Phoenix. 32 people surveyed eat fish from the ponds, 27 do not eat fish from the ponds, while 5 people said that they would like to eat the fish if they caught any, demonstrating that the majority (58%) of individuals eat or would like to eat fish from the ponds, as shown in Figure 2. The reasons mentioned by those that do not eat fish from the pond (27 responses) include that people only fish for recreation (12), do not like the taste of fish (5), believe that the water quality is poor (4), give away their fish to friends (4), have not caught fish yet (2), or are not from the Phoenix area (1).

![Figure 2. Percentage of Individuals who Eat Lake Fish](image)

Question 5 also asked how many times in the past week and in the past month that individuals have eaten the fish from the ponds. The past month amount includes the amount eaten in the past week. This question only asked those who responded that they eat fish from the ponds (32 people). These results encompass fish caught earlier in the year and frozen and also fresh fish caught during that week. In addition, those who responded that they ate fish from the ponds but did not eat any in the last week or month, ate fish on and off at other times during that year or sometime before that. In the past week question, 23 people responded with 0 fish eaten, 5 responded with 1-2 fish, 2 responded with 3-4 fish, and 2 responded with 5-6 fish. Therefore, 23 anglers did not eat fish in the past week, while 9 anglers did. In the past month, 17 people responded with 0 fish, 3 responded with 1-2 fish, 8 responded with 3-4 fish, 2 responded with 5-6 fish, and 2 responded with 7 or more fish. 17 anglers did not eat fish in the past month, while 15 individuals did. While the majority of respondents did not eat fish in the past week/month, there was still a notable percentage of individuals from the 64 sample size that regularly ate fish from the pond in the past week/month because 14% of individuals ate fish in the past week, while 23% of individuals ate fish in the past month. The results for the amount eaten per week and amount eaten per month can be found in the Appendices.

Not only are the anglers eating the fish but they are also sharing it with family members, neighbors, and friends. Question 6 aimed to better understand if and who the anglers were
sharing their fish with out of the 32 respondents that eat fish. The exact count of how many individuals each angler shared their fish with was not captured. The question was not mutually exclusive, anglers could respond to one or all categories. It was found that 19 individuals shared it with a spouse or partner, 19 shared it with children under 18, 17 shared it with other adult family members, and 6 shared it with neighbors or friends. The survey concluded that 84% of anglers that eat the fish shared it with another friend or family member, while 16% only eat it by themselves. Question 6 also had a sub-question which captured the most common types of fish eaten by the anglers. Again, these are not a count of the fish but just the responses. Anglers could answer one or all of the categories. Figure 3 shows that 34 individuals ate catfish, 28 ate trout, 8 ate bass, 3 ate bluegill, 2 ate sunfish, and 2 ate carp. Therefore, catfish and trout are the most commonly eaten fish. Along with finding what fish were eaten, Question 7 found how the fish were prepared and cooked, which is related to the toxicity of the fish. All individuals responded that they either gutted or filleted the fish, depending on the type of fish that was eaten. Question 7 also asked how the fish was cooked and respondents could list one or more ways of cooking, depending on the type of fish. 21 people fried the fish, 7 baked it, 7 grilled it, 4 boiled it, 2 barbequed it, and 2 cooked it in other ways.

Question 9 asked anglers what their perceptions of the environment were at the specific urban fishery they were surveyed at. Anglers were asked to rank water, fish, and land quality on a scale from 1 to 5. 1 being the dirtiest and 5 being the cleanest, then the results were separated into 1-2=dirty, 3=medium, and 4-5=clean. Figure 4 shows the results in a stacked bar chart of 64 responses. When asked about water quality, 23 people said it was clean, 24 said it was medium, and 17 said it was dirty. Overall, water had the lowest perception of environmental quality. When asked about fish quality, 52 people said it was clean, 8 said it was medium, and 4 said it was dirty. Fish was ranked the highest environmental quality, out of the 3 categories. When asked about land quality, 46 people said it was clean, 12 said it was medium, while 6 said it was dirty.
In addition, cross analysis using pivot charts was completed to show interesting correlations between behavior and environmental perceptions. Of the 27 people that said they do not eat the fish, 9 said the water was clean, 12 said the water was medium, and 6 said the water was dirty. Of the 32 individuals that said they do eat the fish, 11 said the water was clean, 12 said the water was medium, and 9 said the water was dirty. Of the 5 people that said they would eat fish from the ponds if they caught one, 3 said that the water was clean and 2 said the water was dirty. Of the 27 people that said they do not eat fish from the ponds, 22 said the fish were clean, 4 said they were medium, and 1 said they were dirty. Of the 32 anglers that do eat the fish, 27 said the fish were clean, 3 said they were medium, and 2 said they were dirty. Of the 5 individuals that would eat the fish if they caught them, 3 said the fish were clean, 1 said they were medium, and 1 said they were dirty. Table 1 shows a disconnection between water and fish relationship perceptions based on the 64 responses.

<table>
<thead>
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<th>Table 1. Water vs. Fish Perceptions</th>
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<tr>
<td>Water=clean, Fish=medium</td>
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<td>Water=dirty, Fish=clean</td>
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<tr>
<td>Water=medium, Fish=clean</td>
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<tr>
<td>Water=dirty, Fish=medium</td>
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<td><strong>Total</strong></td>
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The majority (51% of all respondents) ranked water quality differently than they ranked fish quality, with 19 ranking water as medium quality and fish as clean, while 11 ranked water as dirty and fish as clean.

**Observation Results**

The observation results captured the overall image of environmental quality at each site for each visit. It also aimed to gain socioeconomic information on males, females, ages, and families. However, there were many observation errors in the socioeconomic section of the observation protocol and the results were thrown out. Therefore, the results used will be
environmental observations. Observation protocol information can be found in Appendix E. Based on the surveyor’s observation, Alvord Lake’s overall land, water, and fish quality was medium. Cortez was ranked dirty. Desert West was ranked medium, Encanto Lake was ranked clean. Steele Indian School Lake was ranked clean. Papago Ponds was ranked clean. Most of the land area in the parks that the lakes were located in had little trash, as it is cleaned up by maintenance workers certain days of the week. However, days that the parks had not been cleaned yet did have trash, mainly consisting of plastic based items and cigarettes, concentrated in certain areas, especially near picnic tables, gathering areas, and trash/recycling cans. Cortez Park had the most visible land and water trash. Varying amounts of algae were visible in all lakes.

**DISCUSSION**

Water sampling results at the 6 Phoenix locations showed that numerous pollutants find their way into surface waterways, especially plastics, PCBs, pesticides, and several unknown chemicals. The lakes are located in parks and near golf courses, which use pesticides to maintain grass. Pesticides inevitably flow into the waters and canals after irrigation or rain, resulting in pesticide contamination. Bentiocarb, a common pesticide in the lakes, can be moderately to highly toxic to aquatic life. For acute human toxicity, the Pesticide Action Network (PAN) lists it as moderately toxic and a “PAN Bad Actor Chemical” due to the fact that it is a cholinesterase inhibitor in humans. The World Health Organization (WHO) lists it as moderately hazardous, while the EPA ranks it as slightly toxic. However, much is still unknown about the effects of bentiocarb on humans (Pesticide Action Network, 2014).

Polychlorinated biphenyls (PCBs) remain in the environment from past uses many years ago. PCBs are known carcinogens. Plastics are present because litter is blown into the lakes since these waters are located in urban areas, near high amounts of land trash. Even though there are maintenance workers that clean the surrounding areas on certain days of the week, there is enough litter that blows into the lakes for contaminants to appear in the testing. Plastics were in the form of phthalates and all of the lakes contained DEHP, which the CDC anticipates to be a human carcinogen, while the EPA has determined that it is a probable carcinogen (Agency for Toxic Substances and Disease Registry, 2002). Ingested in small doses, it does not pose a problem but the effects of long term exposure have yet to be determined because few studies on chronic toxicity of DEHP exist.

The survey results showed that the majority (58%) of anglers responded that they eat fish or would like to eat fish from the waters, as shown in the figure below. In addition, it also found that about 14% of individuals ate fish in the past week, while 23% of individuals ate fish in the past month, indicating that a significant percentage of individuals are regularly eating fish from the lakes. Another finding was that anglers are fishing throughout all or most of the year, demonstrating that the anglers and their families that eat fish from the pond may be eating fish
all or most of the year. Eating fish regularly throughout the year for many years can lead to chronic health issues due to eating polluted fish over time.

Question 5 showed that the majority (58%) of anglers responded that they eat fish or would like to eat fish from the waters. In addition, Question 5 also found that about 14% of individuals ate fish in the past week, while 23% of individuals ate fish in the past month, indicating that a significant percentage of individuals are regularly eating fish from the lakes. Question 3 showed that anglers are fishing throughout all or most of the year, demonstrating that the anglers that eat fish from the ponds may be eating fish all or most of the year. Eating fish regularly throughout the year for many years can lead to chronic health issues due to eating polluted fish over time. A part of Question 5 was designed to capture if individuals were not eating fish due to health concern reasons, which was not the case, as only 4 people responded with “water quality perceptions.” The main reason people did not eat fish from the ponds is that they were only there to catch the fish and release them. However, there may have been other reasons underlying “recreation” that were not explicitly stated such as water/fish quality perceptions, laziness to prepare the fish for eating, and ethical reasons for not killing fish.

It is important to understand not only how regularly anglers ate the fish but also who they are sharing it with. Question 6 found that 84% of individuals that said they eat the fish also share it with other friends or family members. Therefore, chronic health concerns impact more than just the anglers but also those that they share their fish with, which could potentially include pregnant women and children. From the study, it was found that about 19 anglers responded that they share their fish with children under 18, which is a problem since pollutants can have greater impacts on children than adults. Another important aspect to acknowledge from Question 6 is that the most commonly eaten fish was catfish, which is a species of bottom-feeder. Catfish accumulate pollutants more than other species of non-bottom feeding fish, possibly leading to greater chronic toxicity if consumed (EPA, 2014).

All individuals responded that they either gutted or filleted the fish, depending on the type of fish that was eaten, which reduces the amount of pollutants. However, most people fried the fish, which is a poor way to cook it, as frying seals the pollutants into the fish, compared to other methods of cooking. In addition, 4 people boiled the fish which is also another method which traps more pollutants into the fish than other methods, especially if it is in a soup or broth that the fish is cooked in. The EPA recommends that the fish be baked, grilled, or broiled to reduce pollutants, which was the way a good amount (14) of individuals cooked their fish (EPA, 2014).

Perceptions of water, fish, and land quality differed. Water quality was ranked the lowest, which had a mix of clean, medium, and dirty rankings, compared to land and fish quality, which had mostly high quality reviews. Out of those who ate the fish (32 people), most ranked that the water was dirty while ranking the fish as clean, which is why many still choose
to eat the fish from the water even if they think that the water is dirty. While surveying, many commented that they thought the fish were clean because fish came from hatcheries, even if they thought the water was dirty. Those that do not eat the fish had similar perceptions but the primary reason, as discussed earlier, that they do not eat fish from the ponds is because they only like fishing for recreational purposes. A closer look at Table 1 shows that the majority of anglers surveyed ranked water differently than fish, with 11 people ranking them completely opposite, with water as dirty and fish as clean.

These results demonstrate the lack of knowledge of the relationship between water quality and fish quality. Many individuals fish from the lakes right after they are stocked, believing that the fish have not had time to accumulate pollutants, which is not true. Fish can accumulate pollutants the moment that they enter the water. The concentrations depend on the type of pollutant and fish. Some contaminants, such as heavy metals, take longer to accumulate in fish, whereas other pollutants only take a few seconds. This finding provides the case for greater education and available knowledge for anglers so they can better understand the relationships between water and fish quality.

The observation data does not correlate with the water sampling data of the amount of pollutants present. For example, locations such as Cortez Lake appeared to be highly polluted, but only contained 10 pollutant types, whereas Steele Indian School Lake looked clean and contained 12 pollutant types. These observation results illustrate how just through observation, no one can actually know how polluted a water body is just by looking at it. In addition, determining the pollution level in fish is very difficult to detect as there may be no outward signs of contamination. This can lead to misconceptions about the relationship between land, water, and fish quality that many Phoenix urban anglers appear to have.

**Demographics**

From an environmental justice perspective, it is important to understand who is being affected by poor water quality in Phoenix fishing ponds. Information from the U.S. Census 2010 and the American Community Survey (ACS) 2009-2013 was used by Arizona Council of Governments and Municipal Planning Organizations to create an interactive demographic map of Arizona, which can zoom in on any city. In this case, Phoenix was the focus. This map was paired with neighborhood information from the survey. Most individuals responded to Question 1 that it took anywhere between 0-10 minutes to travel by car to the park they were fishing at, which generally means the recreational lake is in their neighborhood. This map shows various indicators, such as high minority populations, low median household incomes, and high percentages of families below poverty level, in neighborhoods around the 6 fishing ponds in Phoenix. However, these values vary from place to place and can be inconsistent.

The immediate Alvord Lake neighborhood demonstrated high minority populations of mainly 55-75% and 78-100%, with a medium to high median household income at $56,528-
$80,346, and a low percentage of families below income level at 7-18%. However, not far from the immediate neighborhood, families below poverty level were significantly higher at 32-50% and 50-100%. The Cortez Lake area showed a diverse racial population, with minority percentage values anywhere from 20-35% to 78-100%. The median household income levels were low to medium at $4,519-$36,515 and $36,515-$56,528, and a good amount of families in the immediate area were below poverty level at 18-32% and 32-50%, but nearby, there were less with 0-7%. Desert West neighborhood had a high minority population at 78-100%, a lower to middle median household income level of $4,519-$36,515 and $36,515 - $56,528, and a mix of medium to high percentages of families below poverty level, mostly at 18-32% and 32-50%.

The immediate Steele Indian School Lake area exhibited a low to middle minority population mainly at 20-35% and 35-55%, a low median household income mostly at $4,519-$36,515, with some at $36,515-$56,518, and a low percentage of families below poverty level with mostly 7-18%. However, an area not far from the immediate neighborhood, minority populations were 78-100% with the same area showing 50-100% of families living below poverty level. Papago Ponds neighborhood showed mid to lower minority populations of 20-35% and 35-55%, a mix of household median income levels anywhere from $4,519-$36,515 to $56,528-$80,346, and a low percentage of families below income level at 0-7% and 7-18%. Again, however, there was a high minority population neighborhood of 55-78% and 78-100%, with 50-100% of families living below income level nearby. Encanto Lake area had a mid-lower minority population of 20-35% and 35-55%, a high median household income of $80,346-$114,700 and $114,700-$250,001, and a low percentage of families below income level of 0-7% and 7-18%. Just outside of the immediate area, minority populations were 78-100% with median household incomes at $4,519-$36,515, and 50-100% families below poverty level. The 6 fishing locations, represented by the black dots, and their demographic information is shown below in Figures 5-7.

**Figure 5. Percentage of Minority Populations in 6 Phoenix Fishing Locations**
The issue of polluted recreational fishing waters goes beyond just human health and ecosystem perspectives, there is a socioeconomic and racial aspect as well. These lakes are located in high minority and low-income level areas and most anglers live about 10 minutes or less away. Therefore, many minority or low-income individuals and their families are eating fish from ponds with potentially chronic-disease causing pollutants. Anglers and their families may not be able to afford fish at the supermarket and therefore, they supplement their diet with the fish from the polluted ponds for many years. In addition, studies at the James River, VA, the Florida Everglades, the Savannah River, GA, and the Great Lakes, NY, also found that African Americans were more likely to eat fish from waters with fish advisories and also eat larger portions than Caucasians, due to a number of reasons, such as education about water and fish relationships, adherence to cultural and traditional knowledge and practices, access to fish
advisory information, and ability to interpret fish advisories. These studies demonstrate that recreational fisheries around the U.S. encompass environmental justice issues for low-income and minority populations (Harris and Jones, 2008; Fleming et al., 1995; Burger et al., 1999; Beehler et al., 2001). Therefore, current fishing advisories alone may not be the best option for the protection of recreational fishing waters for certain demographic groups. A different strategy for protecting the health of recreational anglers should be considered.

Recommendations

An ecosystem approach would be the best path for the protection of recreational waters as it incorporates the health of the ecosystem and anglers, the input from the fishing community, and the maintenance of the local economy.

“The ecosystem approach strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems, and their interactions, and applying an integrated approach to fisheries within ecologically meaningful boundaries. The ecological services thus derived from the aquatic ecosystems and fish stocks comprise services that are supporting (e.g. nutrient cycling), regulating (e.g. water quality), provisioning (e.g. fish yield, recreational fishing experience) and cultural (e.g. existence value, spiritual and educational dimension) (Hickley, 2009, p. 175).”

Due to the holistic nature of an ecosystem approach, stakeholder engagement is an important component. This approach would give voice to anglers living in disenfranchised communities that may not have been previously heard to better their recreational parks and lakes (Hickley, 2009). Many anglers at Phoenix urban fisheries stated that they are not responsible for polluting the waters with litter and wish that the waters were cleaner. Most of the anglers believed that those just passing through the parks were the ones that left trash on the land. This situation presents an opportunity for government engagement to empower local anglers to maintain the common good of the urban fisheries and parks through programs and community-building events. Engagement would also create a sense of place and responsibility for the land for anglers and park-users alike so that they are compelled to not litter and keep the area clean.

Current water regulation within the U.S. is governed at multiple scales by various departments, with little communication between these departments. For example, the EPA provides guidelines for surface water pollution, while states create their own standards. The AZ Game and Fish department manages urban fisheries within the cities, while the City of Phoenix government primarily manages the grassy park areas. Other various government entities also may be present in urban fishery management. Therefore, a disconnect exists between the interconnected parts of the urban fishery management system. Following an ecosystem approach means that governmental departments would need to cooperate and communicate.
with each other to work on interdisciplinary, complex issues that pertain to all parts of the recreational fishing water situation. Love et al. 2003 promote not only intrastate but also interstate communication, especially for advisories. They wrote: “creating policies that require rigorous state-level interagency collaboration before releasing fish advisories to the public could better protect fishers and others from consuming contaminated seafood (p. E19).” Interagency cooperation also follows the ecosystem approach in that it “recognizes that human health, diet, food supply, and environmental health are intricately connected (Love et al., 2003, p. E19).”

A significant part of the ecosystem approach should be nonpoint source pollutant controls. Nonpoint source pollution is a common way that recreational waters and the fish that anglers are eating become contaminated. Therefore, better regulation, enforcement, education, and incentives should be used to increase the protection of recreational waters. First, it is important to collect baseline data for the urban fisheries, using technology that detects a large range of chronic and acute pollutants. Next, nonpoint pollution can be controlled through various methods. One of the main contaminants are pesticides which probably originate from the nearby park and golf courses. Government entities which own these lands should develop more sustainable maintenance techniques which reduce or eliminate the use of pesticides near recreational waters. If the land is owned by a private company, incentives or regulations should be presented to the land owners, such as fines, tax breaks, or subsidies to not use harmful pesticides. The surrounding park area and neighborhood should also be cleaned of trash more frequently to reduce plastic litter (phthalates) going into the waters. PCB’s may be extremely difficult or impossible to eliminate because they are no longer presently used but remain in the environment from past uses.

If the resources exist and it is practical, recreational waters should be closed and cleaned with available technologies and methods that remove chronic and acute contaminants. Over time, recreational waters should be tested regularly for pollutants to determine improvements in quality and safeness. In addition, more governmental studies should be conducted to find the chronic toxicity of pesticides and phthalates to develop accurate fish advisories, if a water body cannot be cleaned. The fish advisories should be tailored for the Phoenix community demographics and culture, and information should be available outside of just online sources. A study suggests that community-based participatory research (CBPR) can be a successful method for fish advisory and health safety, especially for minority groups (Corburn, 2002). Special consideration needs to be taken to include the entire recreational fishing community, as past studies have shown that minorities are sometimes excluded from receiving the message, as discussed earlier. It may require an education campaign and signage at all urban fisheries in order to include the entire community.
CONCLUSION

Due to the fact that there are large data gaps in chronic toxicological studies of many chemicals found in the recreational fishing waters, connecting our research directly to potential or actual health impacts is limited. Therefore, more knowledge needs to be generated by other researchers to best understand the chronic health risks that anglers are facing. The survey also carried some limitations. For example, it would have been beneficial to know the fish portion sizes, the amount of time (months, years, etc.) that the angler had fished at a specific location, amount of people each angler shared their fish with, the storage of fish (frozen or fresh), perception of health and environmental safety/protection, fish advisory considerations, and greater demographic information about each person. The information would provide better indicators for chronic toxicity, angler knowledge and education, and demographics. In addition, the observation protocol also should include a ranking of each environmental indicator such as water, fish, and land, similar to the questions in the survey. Another concern is that the survey and observation were only conducted over a 4 month long period. Data over 1 year or more would have increased the sample size and credibility of the study. These are considerations if the survey is continued in the future. The next step is for the Polidoro lab to convert the pollutant concentrations to fish consumption concentrations and to analyze these results based on known recommended amounts, which will be done for the final publishable report.

Recreational water pollution is an issue that goes beyond just the Phoenix area. It is a problem that expanses all 50 states, due to the lack of regulation and control of nonpoint source pollution. Minority and low-income areas are especially vulnerable to consuming contaminated fish and should be considered in future research and regulations. It can be a daunting task to overcome complex sustainability issues. However, instead of viewing recreational water protection as an unbeatable challenge, it should be seen as an opportunity to change the way that we think, research, and regulate recreational water bodies. Following an ecosystem approach which incorporates sustainability pillars such as environment, economy, and society will generate solutions to complex, interconnected problems and will provide the necessary changes within our government-community systems.
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REFERENCES


APPENDICES

Appendix A

Contaminants in Phoenix Urban Fisheries

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<tr>
<th>Count</th>
<th>Alvord</th>
<th>Cortez</th>
<th>Desert West</th>
<th>Encanto</th>
<th>Steele Indian School</th>
<th>Papago</th>
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<td>Diethyl phthalate</td>
<td>Diethyl phthalate</td>
</tr>
<tr>
<td>3</td>
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<td>Benzocarb</td>
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<td>Benzocarb</td>
</tr>
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<td>4</td>
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<td>Malathion</td>
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<td>Dibutyl phthalate</td>
<td>Malathion</td>
</tr>
<tr>
<td>5</td>
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<td>Di(2-ethylhexyl) phthalate</td>
<td>Di(2-ethylhexyl) phthalate</td>
<td>Di(2-ethylhexyl) phthalate</td>
<td>Benthicarb</td>
<td>4-Bromophenyl ether</td>
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<td>?? unknown_1??</td>
<td>Malathion</td>
<td>2,2',4,5'-Tetrachlorobiphenyl</td>
</tr>
<tr>
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<td>?? unknown_4 ??</td>
<td>?? unknown_1??</td>
<td>Ethion</td>
<td>?? unknown_1??</td>
</tr>
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<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>Di(2-ethylhexyl) phthalate</td>
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<td>?? unknown_6 ??</td>
<td>?? unknown_6 ??</td>
<td>?? unknown_6 ??</td>
<td>?? unknown_6 ??</td>
<td>?? unknown_6 ??</td>
</tr>
<tr>
<td>10</td>
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<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>2,3,4,4',5' Pentachlorobiphenyl</td>
<td>?? unknown_1??</td>
</tr>
<tr>
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<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>Malathion</td>
<td>?? unknown_1??</td>
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<td>?? unknown_6 ??</td>
<td>?? unknown_6 ??</td>
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<td>?? unknown_6 ??</td>
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<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>2,3,4,4',5-Pentachlorobiphenyl</td>
<td>?? unknown_1??</td>
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<tr>
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<td>?? unknown_1??</td>
<td>?? unknown_1??</td>
<td>Di(2-ethylhexyl) phthalate</td>
<td>?? unknown_1??</td>
</tr>
<tr>
<td>15</td>
<td>Indeno(1,2,3-cd)pyrene</td>
<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
<td>?? unknown_4 ??</td>
</tr>
</tbody>
</table>

Appendix B

Recreational Fishing Survey

1a. Is this park in your neighborhood?
   1b. How long does it take for you to get here (mins/hrs by car, bike, walking, bus, etc.)?

2. How often do you fish here?
   _____ times a week
   _____ times a month
   _____ times a year

3. During what months do you typically fish here?

4. Have you ever caught fish here? Y/N (If no, ask 5b): [If you have not caught any fish, which species would you want to catch?]

5a. How often have you caught fish in this park?
   _____ times during the past week
   _____ times during the past month
   _____ times during the past year

5b. What species/types of fish have you caught here? [[If you have not caught any fish, which species would you want to catch?]]

5c. Do you ever eat the fish that you catch? Y/N (If the interviewee never eats any fish and never plans to – ask them WHY and go to Question 9a).

   *No*-Why/why not?

5d. How often have you eaten the fish that you catch?
   _____ times during the past week
   _____ times during the past month
   _____ times during the past year

6a. Who in your household eats the fish that you catch?

6b. What fish species do you and/or your household eat?

6c. Which of these do you and/or your household eat the most often? Which do you and/or your household eat the least often?

7. How is the fish that you catch prepared for eating? What are the most frequently used cooking recipes? Are these associated with specific types of fish? [[If you haven’t caught any fish, what is your favorite fish recipe?]]

8a. Does your household buy fish from the supermarket? [If no, ask why or why not?]

   *No*-Why/why not?

   8b. How often do you eat fish at home, that you buy from the supermarket?
      _____ per week
      _____ per month
      _____ per year

   8c. If more than 0 times, what species of fish does your household generally buy from the supermarket?

   8d. On average, does your household tend to eat more fish or more meat, each week?
9a. How would you rate the cleanliness of the water in the park on a scale from 1 to 5, with 1 being the dirtiest and 5 being the cleanest?

<table>
<thead>
<tr>
<th>Dirty</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Clean</th>
</tr>
</thead>
</table>

9b. How would you rate the cleanliness of the fish?

<table>
<thead>
<tr>
<th>Dirty</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Clean</th>
</tr>
</thead>
</table>

9c. How would you rate the cleanliness of the land?

<table>
<thead>
<tr>
<th>Dirty</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Clean</th>
</tr>
</thead>
</table>

10. Where else in the Phoenix area do you like to go fishing?

---

**Appendix C**

**Fish Eaten in Past Week**

<table>
<thead>
<tr>
<th>Number of Responses</th>
<th>Fish Eaten</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>1-2</td>
</tr>
<tr>
<td>15</td>
<td>3-4</td>
</tr>
<tr>
<td>10</td>
<td>5-6</td>
</tr>
<tr>
<td>5</td>
<td>7+</td>
</tr>
</tbody>
</table>

**Appendix D**

**Fish Eaten in Past Month**

<table>
<thead>
<tr>
<th>Number of Responses</th>
<th>Fish Eaten</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>1-2</td>
</tr>
<tr>
<td>10</td>
<td>3-4</td>
</tr>
<tr>
<td>5</td>
<td>5-6</td>
</tr>
<tr>
<td>2</td>
<td>7+</td>
</tr>
</tbody>
</table>
Appendix E

Recreational Fishing Observation Protocol

Description of the fishing area (retrospect): e.g.: How large is body of water/fishing area? What is vegetation make-up? What and when are the fish being stocked in the water?

What is the overall state of the environment (water, land, air, biotic life) on a scale from 1 to 5, 1 being the dirtiest and 5 being the cleanest?

<table>
<thead>
<tr>
<th>Dirty</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Clean</th>
</tr>
</thead>
</table>

Description of overall environmental quality: What do you see? Is it spotless? Or are there beer bottles, syringes, cigarette butts, etc. lying around or in the water?

Approximately, how much visible trash is in the water?
Small (s), Medium (m), Large (l)

Approximately, how much visible trash is on land?
Small (s), Medium (m), Large (l)

What (if any) is the algal cover of the water body?
Small (s), Medium (m), Large (l)

What is the quality of the smell of the water on a scale from 1 to 5, 1 being the dirtiest and 5 being the cleanest?

<table>
<thead>
<tr>
<th>Dirty</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Clean</th>
</tr>
</thead>
</table>

Description of smell, if any:

Comparison of perceived cleanliness to water quality samples taken by research team (Written after observation):

Bird Populations: How many? Species?